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AUTHOR Martens, R. L.; And Others
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ABSTRACT

The use of embedded support devices (ESDs) has been studied in previous research that has unfortunately demanded introspection and reflection on one's own cognitive functioning. In contrast, eye movement registration measures the attentional focus of students on specific text parts regardless of whether or not the student is conscious of this focus. Earlier research has indicated that ESDs are used at a deep level, and not superficially read. Eleven college students read slides from a chapter of a governmental law course from the Open University of the Netherlands. Eye movements were monitored through the corneal reflection/pupil center technique and computer analysis. Eye movement patterns were compared for text with ESDs and text without ESDs. The average reading time per word was in line with expectations for most ESDs. Every ESD was looked at least once by each student. Limitations and possibilities for improvement of the research technique are discussed. Five figures and six tables illustrate study findings. (Contains 67 references.) (SLD)

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Eye movement registration during studying: An explorative study of the use of embedded support devices

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R.L. Martens
P.H.A.G. Poelmans
M.M. Daal
M.M.A. Valcke
J. Stolk

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The main objectives are in the field of flexible organization of support, incorporation of support into learning materials, optimizing the link between student characteristics and the support needs, and the development of more flexible (and automatised) approaches towards student guidance.

Centre for Educational Technology and Innovation
Open university

Eye movements registration during studying: An explorative study of the use of embedded support devices[1]

OTIC Research Report 64

R.L. Martens
P.H.A.G. Poelmans
M.M. Daal
M.M.A. Valcke
J. Stolk

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Centre for Educational Technology
and Innovation, Ou
OTIC secretariat
PO Box 2960
6401 DL Heerlen
The Netherlands
Telephone +31 45 762317 (- 772)

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Abstract

In previous OTIC-research the use of embedded support devices (ESD) has been investigated by making use of interviews and questionnaires. An important disadvantage of these research methods is that they demand introspection and reflection on one's own cognitive functioning. In contrast, eye movement registration is very different in this perspective. The attentional focus of students on specific text parts is registered, regardless of the question whether the student is conscious about this. Using a research set-up based on this method we wanted to check and replicate findings of our earlier research on the use of ESD in self-instructional materials: ESD are used at a deep level and are not superficially read.

Eleven subjects participated in this research. Slides were projected with a projector on a screen in front of the subjects. The slides depicted pages of a learning unit (chapter) of the Ou-course 'Introduction to governmental law'. The eye movements were monitored by means of the corneal reflection/pupil centre technique with an infrared camera. With the computer programs 'EYECATCH' and 'EYEANAL" the data of the eye movements were recorded and analyzed. Eye movement patterns were compared between text parts with ESD and those without ESD. For each text part the computer program computed the total reading time per selected area. From this the reading time per word was computed. In relation to 'schemes', also the number of 'jumps' between the text and back to the scheme were recorded.

It was found that the average reading time per word was for most ESD in line with our expectations. For instance content pages have shorter reading times per word and questions are read longer per word. 'Schemes' invoke ± 3.6 jumps to other text parts. Furthermore it turned out that every ESD analyzed was looked at, at least once by each student. This first study, making use of the eye registration technique is to be considered as a first attempt to approach the study of ESD use with new research techniques. Shortcomings and possibilities for improvement are discussed.

1 Introduction

In the context of distance education the quality of study materials is of prime importance. The study materials of the Open university of the Netherlands (Ou) are still mainly based on printed text. Much energy and time is invested to generate these materials. An essential part of the printed study text (up to 40%) consists of embedded support devices (e.g. content pages, examples, advanced organizers, pre- and postquestions, schemes, tests, margin texts). Embedded support devices (ESD) are defined as formal and/or content-related add-ons, extensions and elaborations of the learning content in printed study materials. They aim at scaffolding the learning process by supporting (a) the orientation, (b) the planning, (c) the processing and the (d) evaluative aspects of the individual learning process.
This research has been set up as part of the project 'Course Versions' The project focuses on the effects of course versions on study outcomes. Especially, the effect of varying the amount of ESD is of main interest. The key question of this project is: "Is the high investment in the design and elaboration of printed study materials worth the effort?" The key questions of the 'Course Versions' project are related to the 'effects' of ESD on study outcomes/results. The present research elaborates on findings of earlier OTIC-research by making use of a different research method.

Research methods used in earlier research (for instance Martens, Poelmans, Daal, van Staa & van Meurs, 1993; Valcke, Martens, Poelmans, Daal, 1993) were based on questionnaires and interviews. An important disadvantage of these two research methods is that they build on introspection and reflection on one's own cognitive functioning. This is in sharp contrast with the overall accepted statement that a great deal of the study process occurs at subconscious level (Resnick, 1987). Using interviews or printed questionnaires therefore incorporates the risk of underestimating or mistaking functions and effects of ESD. Just & Carpenter (1977, p.1) state: "For most adults, comprehension is rapid, automatic and effortless. But, despite of its apparent simplicity, comprehension includes a myriad of subprocesses, each of which by itself constitutes a formidable computational task. (...) All these processes occur so quickly that their richness is underestimated. Because of the sheer speed of comprehension, it is difficult for the reader to explain how he came to understand a passage. That task is left to those who study comprehension."
It is as a consequence difficult to get access to these processes, certainly if this is done by means of interviews or questionnaires. To overcome this problem other research methods are desirable (Valcke & Martens, 1992). The eye movement registration method is in this perspective very efficient since the research method does not build on reflection or monitoring of the personal study process. The attentional focus of students on specific text parts is registered, whether the student is conscious about this process or not. In this study, we will use eye movement registration techniques to investigate the use of ESD in course materials of the Ou.

This research report starts with an overview of earlier research. Chapter 3 includes a short summary of the theoretical base and background of our research in order to state the research hypotheses. Chapter 4 focuses on the description of the research design. Attention is paid to the selection of the research sample, the research instruments, the eye movement registration procedure, the research procedure and the preparation of the data set for further analysis. Furthermore we pay attention to the potential distracting nature of the particular research design and reliability and validity issues. After discussing characteristics of the research sample, the analysis procedure of the research data is presented in chapter 5. In chapter 6 we discuss the research results in view of the hypotheses put forward.

2 Earlier research

Embedded support devices, such as objectives, questions, schemes, examples, etc. have been the subject of a vast body of research since printed texts play a major role in educational contexts. In the seventies and eighties some major reviews of this research have been elaborated (cf. Alesandrini, 1984; Barnes & Clawson, 1975; Hartley & Davies, 1976; MacDonald-Ross, 1977; Rothkopf, 1970; Waller, 1979; etcetera).

This section focuses first of all on earlier research conducted outside the Ou of the Netherlands. In an earlier research report an extensive overview has already been presented (Valcke & Martens, 1992). therefore, we centre in this report on the general results of this overview and especially expose important shortcomings of the research tradition in this field.

In a second subpart an overview of research conducted at the Ou of the Netherlands is presented. This section shows how the research reported here builds on earlier findings and focuses on alternative research methods.

2.1 Research

Limited amount of research in a distance education context

Clyde and Crowther (1983, p.4) clearly point at a major shortcoming of research in relation to distance education when they state: "Despite the growth of distance education, little systematic knowledge is available concerning the ways in which students use the distance teaching materials provided to them." (cf. also Marland, Patching, Putt & Putt, 1990). Despite the high investment in ESD by course developers, little is known about there functions and effects in study materials. This is particularly true if we focus on research in a 'distance education' context.

Doubts about functions and effects of ESD

Most ESD are designed to evoke some kind of behaviour of students. Wade and Trathen (1989, p. 40) however state: "(...) despite their popularity, there is no consistent empirical evidence that these techniques are any more effective than more passive methods of reading-only or repetitive reading...". Even when - from a theoretical point of view - functions and effects are assigned to specific ESD, there is the problem that Meyer and Watson (1991) have signalled: practical implications derived from this are often not useful.

Doubts about student use of ESD

Many research on ESD is marred by the fact that researchers hardly know what learners do when they are presented with text-embedded support. It is for instance not sure whether or not they actually use or know how to use these support facilities (Winne, 1983). We must not forget that the student - when working at a distance with printed learning materials - has complete veto power over learning (Rothkopf, 1970). Winne (1983, p.245) states for example when he tries to explain the inconsistencies in earlier research results : "these results may reflect different ways that learners cognitively responded to the instructional stimuli rather than weaknesses in their effects". In order to obtain more valid results, this researcher trains his students to use the embedded support devices (objectives, adjunct postquestions). A similar approach is adopted by Bernard (1990) and de Jong & Simons (1988).

The question is not only whether students use the support devices or whether they know how to use them, but also whether they need the support provided. ESD are only useful if students need them. Waller (1979) mentions e.g. different user objectives when dealing with study texts: entertainment, recapitulation/reviewing, browsing, studying in depth, searching for a particular item. Each user perspective affects the potential effects/functions of ESD.

Methodological problems
Valcke & Martens (1992) stated that the ecological validity of many research set-ups is questionable. Research is hardly set up in a distance education context and mostly not in natural learning contexts. Most research is set up in isolated lab-like settings (cf. Lockwood, 1993).

Theoretical problems
Finally, serious theoretical problems can be put forward when analyzing the research in the literature. Valcke & Martens (1992) signalled a lack of theoretical base, reductionist approaches and behaviouristic influences that lead to the omission of potentially important variables and an unidimensional approach in which individual effects and interactions are neglected.

2.2 Research at the Ou of the Netherlands

At the Ou of the Netherlands, research in relation to ESD was set up since 1991. We describe in short some of the research-approaches and the main results.

Theoretical framework
A basic phase in the Ou-research was the elaboration of a theory on the potential functions and effects of embedded support devices in printed study materials (Valcke & Martens, 1992). This theoretical model is considered as a starting point from where to look at the actual use of ESD by students when they study course materials.
In reviewing the literature, also methods and instruments were examined to investigate the use, functions and effects of embedded support devices.

Checklist
A checklist was developed to map the occurrence and quality of ESD in a study text, at two levels: course level and learning unit level (Valcke, Daal, Martens & Dochy, 1991).
This checklist was used in a try-out with the course 'Introduction to Governmental Law' and proved to be useful for a systematic mapping of ESD in printed course materials (Martens & Daal, 1992; Martens, Daal & Valcke, 1991). About 40% of the text of Ou study materials consists of ESD.

Research with interview method
In a first research set-up twenty-five law students of the Ou were interviewed about the way they study Ou-learning materials. The interview gradually focused on the use and effects of ESD as perceived by the students (Poelmans, Martens, Daal, Valcke & Dochy, 1992; Valcke, Martens, Poelmans, Daal, 1993). The interview method had the advantage to reveal a considerable amount of detailed information. 25 law students were interviewed.
The research results indicated that students use ESD to a high extent (varying from 60% to 100%) and highly appreciate them. Students who use ESD to a high extent at a deep level, attain a significantly higher final test score and need less attempts to pass the final test (Poelmans et al, 1992). 'Deep level' refers to a concept commonly found in literature about study regulation: surface level versus deep level studying (Marton & Säljö, 1984). Studying at a surface level means 'only' reading and learning by heart, deep level learning puts emphasis on comprehension.

Research with questionnaire method
At the Ou of the Netherlands, the department OID sets up - yearly - an annual evaluative study involving about 2000 students. This annual research is based on the use of questionnaires. Students taking courses in different subject domains participate in the study. In 1992, a part of the questionnaire consisted of questions about ESD their use and links with study success. Researchers of OID and OTIC analyzed the research data (Martens, Poelmans, Daal, van Staa & van Meurs, 1993). The results revealed that students appreciate ESD positively: only 7% of the students appreciate course material without ESD. Students of the subject domain 'Cultural Sciences' appreciated ESD to a lesser extent (Pearson correlation coefficient -.24, $p<0,0001$). No interrelations

between the use of ESD and the level of study success could be found. Study success was in this context operationalised as the speed to attain study credits. For more information about this research with questionnaires and problems that were encountered we refer to van Staa & van Meurs (1992).

Different versions of one course
In another research, the relation between ESD and study results was investigated by adopting a different research design and method. The key question the research focused on was: do ESD have a positive effect on study outcomes? Two versions of a learning unit of the Ou-course 'Introduction to governmental law' were assembled. The first version was almost an exact copy of the original printed text in the Ou-textbook. The second version was about 60% shorter as a result of deleting most embedded support devices (such as schemes, summaries and learning objectives). This omission did not alter the basic content or did not affect the coherence of the text. Thirty-six students from the University of Limburg (RUL) studied one of both course versions. Several tests and questionnaires were developed to measure the effects of course versions on study success and the potential interrelation of study success with independent student variables. No significant effects on study time, student evaluations of the learning access level and 'knowledge' questions could be observed. But students who studied the extensive course version, comprising ESD, achieved significant higher scores on 'insight' questions (T-test with $F=3.47$, $P<0.05$). Interrelations with the independent variables prior knowledge, time used, reading comprehension, educational level and gender were tested. These variables were added to the ANOVA models as covariables. Reading comprehension turned out to have a significant effect (Martens, Poelmans, Daal, Valcke, 1993).

3 Theoretical base

Much effort was invested in developing a theoretical framework to describe and explain the functions and effects of embedded support devices in relation to studying from printed texts. This section summarizes the theoretical base of this research.
First of all key processes and variables are presented. The following variables and processes are considered to be of importance: cognitive aptitudes (3.1 cognitive functioning and 3.2 reading comprehension), non-cognitive aptitudes (3.5 motivation), task environment (3.3) and intra-individual variables (3.4). In section 3.6 we integrate these processes and variables into one consistent theoretical model grounding this research. We refer to Valcke & Martens (1992) for a more extensive description and discussion of the model.
A short overview of eye movement registration research is given in section 3.7. This special research method has to be related to our research set-up and theoretical model.
Section 3.8 focuses on the research hypotheses.

3.1 A cognitive psychological framework

An essential part of the theoretical framework is based on considerations about the nature of cognitive functioning. We opted for instance for the componential theory of Sternberg (1985, 1988) to describe and explain cognitive functioning in our specific distance education context. Sternberg's cognitive processing approach stresses, in one consistent framework, the importance of a large complex of cognitive processes.

Cognitive functioning is - according to Sternberg - described with the concept 'components'. A component is "an elementary information process that operates upon internal representations of objects or symbols" (1986, p.225). Sternberg distinguishes three groups of components:

- Performance components (PC);
- Knowledge acquisition components (KAC);
- Metacognitive components (MC).

Metacognitive components control, evaluate and plan the activities of the other components. They are executive processes. The knowledge acquisition components are involved when new information is integrated in already available information in memory. This integration process implies encoding, combining and comparing. Performance components are those processes that operate when a task is actually executed. Knowledge acquisition and performance components are non-executive processes. The metacognitive components can be perceived as "the stage directors that tell the actors - the performance and knowledge acquisition components - how to act. The actors in turn provide feedback to the directors about how the show is going." (Sternberg, 1988, p.189)".

ESD have a support function for the learning process (PC, KAC, MC). They aim at scaffolding the learning process by supporting orientation, planning, processing and evaluative aspects of the individual learning process.

3.2 Reading comprehension: an important intervening process

As stated earlier, the interference of the reading process in our research cannot be neglected and is even to be incorporated into our model. We focus on 'discourse comprehension' and not on the decoding aspects of the reading process. This decoding process is, for experienced adult readers an automatic process, that probably hardly causes individual differences, although there might be an indirect influence. Though at this level reading and listening have become very similar (Kintsch & van Dijk, 1978; Perfetti & Lesgold, 1977), we will only focus on the comprehension of written texts (discourse).
In this text part, we restrict ourselves to an introduction into recent and main developments in the area of discourse comprehension to be able to relate these reading theories to our theoretical model.

3.2.1 Discourse comprehension

A major publication in the discourse comprehension literature is Kintsch & van Dijk (1978). In this publication, they present the model described below. The model shows how a reader builds a coherent global text meaning from isolated text propositions. The rules, followed through this process are called "macrorules". This model, with minor or major adaptations is still used and still influential in current research and literature (e.g., Rayner & Pollatsek, 1989; Britton & Gülgötz, 1991; Oostendorp en Peeck, 1991).
Discourse comprehension is a complex process that still is not comprehended by theorists (Rayner & Pollatsek, 1989). In recent attempts computer models are built to simulate the process. These simulation programs remain restricted and can be compared to the still imperfect attempts to automate the translation of texts. Good translation requires understanding of the text.
Obstacles in theory construction and research of discourse comprehension is the measurement issue and speculations about the number of 'factors' that should be used to describe this reading skill. Recent theorists adhere the view that the skill is based on a single factor, called 'verbal intelligence', causing individual differences (Rost, 1989). Despite the heavy debates on this issue, there is a certain agreement about the - minimal set of - 'building bricks' constituting a model for discourse comprehension. Kintsch (1988, p.163) : "Discourse comprehension, from the viewpoint of a computational theory, involves constructing a representation of a discourse upon which various

computations can be performed, the outcomes of which are commonly taken as evidence for comprehension. Thus, after comprehending a text, one might reasonably expect to be able to answer questions about it, recall or summarize it, verify statements of it, paraphrase it, and so on.".

At this level, we already perceive cognitive processes that can be related to components of cognitive functioning as described by the Sternberg-model.
Kintsch continues : "To achieve these goals, current theories use representations with several mutually constraining layers. Thus, there is typically a linguistic level of representation, conceptual levels to represent both the local and global meaning and structure of a text (e.g., the micro- and macrostructure, constituting the text base in van Dijk & Kintsch, 1983), and a level at which the text itself has lost its individuality and its information content has become integrated into a larger structure (e.g., van Dijk & Kintsch's situation model)."

Figure 1 gives a schematic overview of the overall construction and functioning of the discourse comprehension model as found in literature (Ballstaedt, 1981). In this figure, the text is the input of the process and the cognitive schemata form the output. The micro- and macrostructure of the text represent subproducts of the comprehension process.
The process starts from a 'text'. This text is decoded : words, meaningful units are extracted from the text. If a text is comprehended and letters/words are turned into meaningful, but still isolated units (micropropositions), these units are combined and a trace is constructed that runs through the text.
The decoding process is done at local text level; small text parts are taken step by step. When words have become meaningful units (but still isolated), these units are combined and the trace that runs through the text is reconstructed. This implies a certain reduction of the initial text content. Moreover, in order to comprehend the text, the reader does also have to know even more than the actual text content. Inferences and elaborations have to be made. Inferences are text additions constructed by the reader; elaborations are inferences that go beyond the minimal information needed to understand the text (e.g., the reader makes a pictorial representation of the main character of the story). Finally, these processes result in a set of cognitive schemata about the text content.

It is taken for granted that the process, described above is of a cyclic nature. Text parts are processed part by part. At the end of the cyclic process, the complete text is comprehended. It is also important to note that there is no strict hierarchy in the processes and building bricks described. All processes influence each other. Of course understanding a text starts with reading the first sentences of a discourse ('bottom-up') but always immediately expectancies, schemata and ideas from the reader start to play an important role (top-down). Moreover, the interpunction of the overall process is not unidirectional; text comprehension does not only start from a newly read text (bottom-up), but is also initiated from existing and available cognitive schemata (top-down). If people read for instance some new text, that is consistent with their content expectations, the text will be read and comprehended at a much faster rate, compared to texts with unexpected content parts. Taking into account these latter remarks, it is to be stressed that the model in Figure 1 is a simplification of reality. The layered structure and process flow suggested in the model, represent rather 'one' possible conception of the comprehension process, compared to processes and the structure in real life. This strong interrelatedness of structure elements, layers and processes is depicted in Figure 1 with arrows : the large arrows represent information flows. The curved arrows suggest a possible process run.
It must be stressed again that there is no agreement yet nor strong evidence for any of the developed models of reading comprehension. There is probably still a long way to go before the process is really understood.

Figure 1 represents the complete scheme of the comprehension process. The outcomes of the process are represented as 'bricks', the process elements are depicted with ellipses. For a description of some other models of reading we refer to Rayner & Pollatsek (1989).

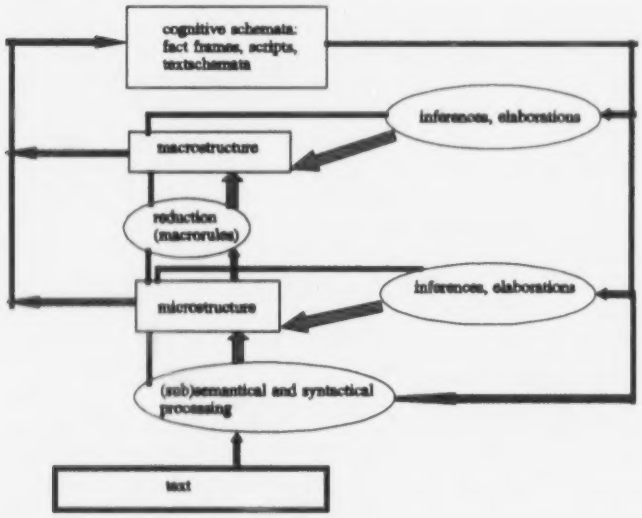

Figure 1: Schematic representation of the building bricks and processes in the comprehension process (based on Ballstaedt, 1981)

3.2.2 Reading and learning

Parallelisms between reading and learning can be found at the level of the nature of input and output (1) and at the process level (2). Differences are striking when the 'intentionality' and 'finality' of both processes are clarified.

-1- Parallelism between the nature of **input and output** of the learning and comprehension process. When recapitulating the comprehension process described above, and looking at the learning process in the context of distance learning, based on written study materials we see that both processes mainly start from a 'text'. At the output level, both processes result in the construction of 'knowledge' (comprehension). Following the Sternberg model the knowledge acquisition components result in coded, combined and compared representations. The comprehension process described earlier results in cognitive 'schemata'. These schemata are comparable to the 'representations' in our conceptual frame of reference. But of course, since students, when learning, are expected to go beyond the mere text content by answering questions, executing tasks, etcetera. The final output of the learning process will be much more complex.

-2- Parallelism in the **process aspects** of the learning and comprehension process.
Since learning from text is based on comprehending the study text in order to extract meaning, in order to perform specific learning processes there is an overlap between both processes at consecutive stages.
If we concentrate on the - in time and function - overlapping cognitive processes between learning and reading (comprehension), we can state that the processes described along the Kintsch and van Dijk model are comparable to the processes in the Sternberg model. Figure 2 shows the possible overlap between both processes in the course of a learning process. Since both processes, in starting from a text, are directed towards meaning construction, the three groups of cognitive components can be used to characterise the subprocesses described in the Kintsch & van Dijk model. In reading, metacomponents are active: there is the problem to be recognized and solved,

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its extent is to be stated, attentional resources are to be allocated, the process is to be monitored, specific strategies for task performance are to be selected, etcetera (cf. Markman, 1979). The knowledge acquisition components are in game when the cognitive schemata are build, step by step, by encoding, combining and comparing (cf. the macrorules of Kintsch & van Dijk). Performance of the selected strategies for task performance is to be guaranteed by encoding, combining and comparing (text) stimuli and applying task specific activities.

- Differences between the comprehension and learning process.
As stated earlier, there is not a complete overlap between the reading and learning process. Learning goes beyond mere reading and comprehending since the learning activated in the text goes beyond the mere text content. Students are expected to solve questions, execute tasks, look for resources or extra documentation, etcetera.
Also the kind of reading, implied by learning is in a way different from reading in general. The type of reading on which learning is based differs from other types of reading by its special 'intentionality'. Reading for studying is for instance different from reading as a leisure activity or reading to search for specific information (van Hout Wolters & Kerstjens, 1990). Reading, when linked to learning can be considered as a kind of extended reading. Just & Carpenter (1987, p. 424) state the interrelation between reading and learning as follows : "Many study strategies can help readers understand the text's content and organization and relate it to what they already know, including rereading, outlining, and networking. These strategies are closely related to normal comprehension processes; they require elaborating on and making explicit the kinds of informational structures that readers construct during comprehension.".
So, the difference between both processes is to be found in the intentionality of the reading process. Oostendorp & Peeck (1991, p. 153) describe this as follows[2] : "...when reading there is not always a learning intention. This means that the process is not directed towards changing a cognitive structure. Learning is always directed towards changes in cognitive structure.". The special intention of learning is also found in the larger stress that is put on the incorporation of knowledge representations (cognitive schemata) into the memory structure in order to remember what has been read. Many researchers (Gernsbacher, 1985; Lorch & Lorch, 1985; Mandler & Johnson, 1977; Thorndyke & Yekovich, 1980; etcetera.) stressed this special interrelation between comprehension, learning and remembering.

In summary, learning can in part be considered as a special case of discourse comprehension that is focused on changes in knowledge acquisition (representation and retention).
Boonman & Kok (1986) adopt a similar view and have constructed an extended reading model (Figure 2). The interesting thing about their model is that they offer us the opportunity to anticipate on our discussion about the potential role of ESD in learning from text. Next to technical reading and text comprehension they discern 'reading for studying'. Here, the learner/reader goes beyond the text and starts processes that are labelled as 'in-depth analysis' which imply repeating, transforming and elaborating[3].

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[2] Translation by the authors of this article.

[3] Note the parallelism between their conceptual framework and the schema theory of Anderson in which learning is approached as a process during which schemata are transformed, tuned and refined (Anderson, R.C., Reynolds, R.E., Schallert, D.L. & Goetz, E.T., 1977; Anderson, R.C., Spiro, R.J. & Anderson, M.C., 1978).

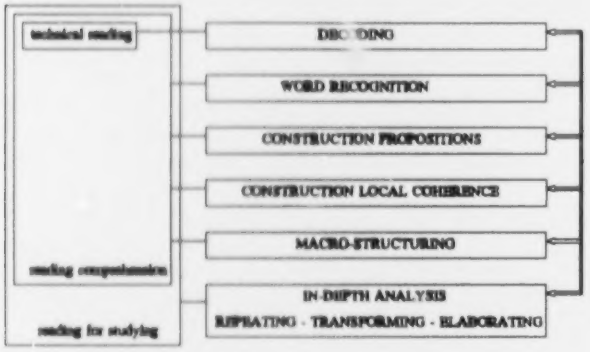

Figure 2 Model of reading for studying (Boonman & Kok, 1986, p.69)

3.2.3 Individual differences

Since discourse comprehension is related to learning, reading ability does correlate to a high degree with educational achievement. Reading ability correlates with school achievement results and general intelligence indicators (Rost, 1989). Individual differences in reading ability are therefore an important intervening variable in the process of learning from text. In literature, (e.g., Singer & Donlan, 1989) 'types' of readers are distinguished. If we look at the building bricks of the model for the reading process, differences between readers can be related to specific elements or process parameters. Oostendorp & Peeck (1991) have derived a long list of differences. It is also important to note that differences between readers can be important and are difficult to overcome (Rost, 1989; Singer & Donlan, 1989) :

- There are differences in the semantical and syntactical base. Less able readers possess for instance a less elaborated vocabulary. They do not only understand concepts to a lesser degree but the slower and non-automatic word recognition process invokes an extra bottleneck by putting too heavy demands on the capacities of the short term memory (cf. also Perfetti & Lesgold, 1977).
  Differences in grammatical knowledge hinders of course text comprehension.
- Differences in speed and accuracy by which concepts are recognized and put in context.
- Differences in prior knowledge (cf. Dochy, 1992)
- Differences in cognitive functioning (components in the Sternberg model).

Next to differences in relation to cognitive aptitudes. Oostendorp en Peeck (1991) also mention differences that go beyond the mere cognitive aptitude differences :

- Differences in interest.
- Differences in motivation (differences in attitudes towards the text content).

As stated before it should be noted that these differences do not occur isolated. Individuals lacking one of these 'abilities' usually lack others.

3.3 The task environment

The task environment refers to those variables that define the setting in which the student studies. These variables show a great variability in a distance education setting.
Learning, in this theoretical framework, is the result of the interaction of an individual with a task environment as defined by the distance education setting in which the student is expected to attain objectives in a self-instructional way, by adopting an independent learning approach.
The task environment can have an influence on the cognitive functioning and the reading process for instance by means of the learning materials provided to a learner. In distance education in most cases the learning materials consist of printed self study materials. Other task environment variables can vary of course a lot across learners since there is no 'control' over these variables in distance education. It is possible that some students have more problems with distracting environmental influences then others.

3.4 Individual variables

The set of potentially relevant individual variables is considerable. For this research we limit this set of variables to the next three subsets.

cognitive functioning:

> There are many intra-individual variables related to differences in cognitive functioning. Some examples are prior knowledge (Dochy, 1992) and crystallized or fluid abilities (Lohman, 1993). Prior knowledge can be an important predictor of study outcome. Differences concerning cognitive functioning are important intervening variables between the input and output of the study process in distance education. Note that these abilities are not necessarily stable and unchangeable. It is evident that prior knowledge can change but this also seems to be the case with intelligence tests. Lohman (1993, p.13): 'Intelligence tests, like achievement tests, measure developed abilities, not innate capacity or potential.'

reading comprehension:

> A particular example of an intra-individual difference in cognitive functioning that can influence study outcome and one that is strongly related to general intelligence ('G') is reading comprehension.

studying texts with/without ESD:

> It has been found that studying texts with ESD has important advantages to students as stated earlier. Comprehension improves and examination results are better. There might however be a relation with individual variables, in other words: do some students benefit more from ESD than others, or do some students use ESD more than others? The research conducted so far has not revealed important differences in the effects of ESD although some groups of students (for instance female students) tend to use ESD more than others.

3.5 Non-cognitive aptitudes: motivation

Studying with self study materials presupposes a strong intrinsic motivation of students to get and stay involved in the study process. Most Ou-students combine their study with a regular job and other duties/tasks for instance as head of a family. Motivation is therefore an, although often neglected in Ou-practice, important variable.
Differences in motivation do not only occur during reading but can influence the complete study process (Boekaerts & Simons, 1993). Motivation is a very complex concept. In fact motivation stands for the mental processes that determine what behaviour an individual performs, how long and with how many effort. So 'motivation' is as a concept almost as broad as psychology itself.

There are many aspects related to it in education like for instance the concept of internal vs. external motivation, reinforcement and fear of failure. In this research motivation does not play a major role so we will not give more attention to the theoretical underpinning of this concept in our research.

3.6 Integrating processes and variables

Figure 3 summarizes the theoretical framework.

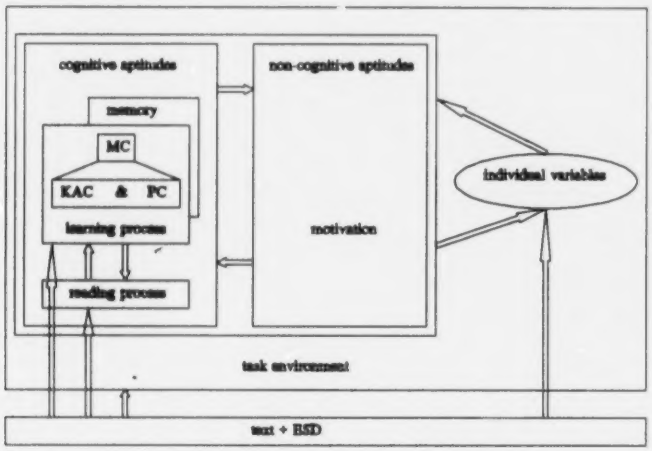

Figure 3: A model for learning from printed study materials

The model in Figure 3 depicts the interaction of the processes described above. In the next section we clarify how the specific research method adopted in this research 'Eye movement registration' builds on this theoretical framework. In part 3.8, we derive from the framework the basic hypotheses for our investigation.

3.7 Eye movement registration research

As explained earlier, eye movement registration was introduced in this project, as an 'extra' to traditional methods, such as questionnaires and interviews. These methods are considered to depend heavily on reflection/introspection and are thus a possible source of subjectivity. Eye movement registration is used as a supplement, not as a substitute for traditional methods, because it has its own problems. One major problem of eye movement registration is that the relation between eye movements and higher psychological functions, such as discourse comprehension, is far less clear than its relation to lower order functions, such as lexical access and word recognition (Rayner and Pollatsek, 1989). However, objectivity is an important virtue of eye movement registration, which makes it worthwhile to explore it as a tool to investigate the use and effects of ESD.

Eye movement registration is used in various research areas ranging from reading research and picture scanning to oculomotor control. In the context of educational research it is still mainly used to study the reading process (van Lieshout, 1982). Initially, it focused on local aspects of the text processing, such as the impact of visual/graphical features or word frequency. McConckie and Rayner (1975) for example tried to determine how peripheric (parafoveal) text influences the

processing of the text in and near the fixation point of the eye.
Increasingly however, researchers became interested in eye movement patterns to study comprehension processes.

- Mandel (1979) and Shebilske & Fisher (1981, 1983) revealed for instance differences in eye movement patterns when reading specific text parts which express key ideas.
- Rothkopf & Billington (1979) discovered differences in eye movement patterns when reading text parts which differ in importance according to the objectives of the reader. In this research set-up students were asked to memorise specific objectives, before reading a text. Reading of goal-relevant sentences resulted in over twice as many and longer fixations (> 15 msec) than less relevant sentences.
- Just & Carpenter (1980) used data from eye movement registration to construct a model to describe reading comprehension.
- Grabe, Antes, Thorson & Kahn (1987) investigated the pattern of eye movements produced when adult readers encounter cross-sentence contradictions. Uninformed subjects were asked to prepare the answer to a question that would follow each paragraph. Informed subjects were told that the paragraphs could contain contradictions and that they had to report the contradictions and to answer a question after each paragraph. Analyses of eye movement patterns provided evidence that both informed and uninformed subjects were aware of the inserted contradiction but that instructions to search for inserted errors caused readers to alter their reading behaviour.
- Blanchard & Iran-Nejad (1987) found that there was an increase in the number of fixations associated with rereading surprising lines of stories when compared to the same lines in a control condition, where these lines were not surprising.
- Vauras, Hyönä and Niemi (1992) examined the effect of text structure on the reading process and recall. Each subject read and studied a coherent and incoherent text. Incoherence was brought about by changing sentence order in central paragraphs of a text. Immediate free recall followed this reading/study process. The eye movement data showed that structural incoherent text segments attracted the largest number of regressive fixations, and hence were given more visual attention than coherent text segments. On the other hand, more rereadings were devoted to text segments resolving the incoherence.

Rayner and Pollatsek (1989) presented figures for fixation duration, saccade length, percentage of regression and the number of words per minute for 10 good college-age readers reading different types of text. We have extended these figures with the reading time per word in order to facilitate comparison with our own results. Table 1 shows the extended figures of Rayner and Pollatsek.

Table 1: Reading characteristics for 10 good college-age readers reading different types of text (adapted from Rayner and Pollatsek, 1989)

topic	fixation duration	saccade length	regressions (%)	words per minute	reading time per word
light fiction	202	9.2	3	365	164
newspaper article	209	8.3	6	321	186
history	222	8.3	4	313	191
psychology	216	8.1	11	308	194
english literature	220	7.9	10	305	197
economics	233	7.0	11	268	223
mathematics	254	7.3	18	243	247
physics	261	6.9	17	238	252
biology	264	6.8	18	233	257
mean	231	7.8	11	288	208

In general, research within cognitive psychology on language processes has been focused on the processing of linguistic information alone (Duffy, 1992). However, most things we read consist of text in combination with other graphical elements, such as pictures, photographs, schemes and tables. Language comprehension of text-picture combinations can be regarded as a new area of research. Recently, a number of studies have become available that start to explore this new area in relation with eye movements (Hegarty, 1992; Carroll, Young and Guertin, 1992). These developments seem relevant in the context of ESD, in general learning material also consists of a mixture of text and other graphical elements.
The studies mentioned above, indicate that the spatial aspects of eye movement, such as the spatial distribution of fixations of a page of study material, are at least equally important as temporal aspects, such as fixation durations and gaze durations.

The eye movement method surely also has disadvantages. The special research set-up affects the ecological validity of the setting. Subjects are asked to study and read in a special setting, including a special chair, head-support and are often not allowed to move their head when reading. Although, it will be shown that subjects did not experience the set-up as disturbing. In our approach, the technique has been chosen to confirm/disconfirm findings of earlier research, which was based on interview and questionnaire techniques. The objectivity of the data obtained with the eye movement registration method would be a valuable counter-balance for the 'subjectivity' of the data source in the earlier research methods adopted.

3.8 Deriving research hypotheses

Previous research on ESD resulted in conclusions we now seek to confirm/disconfirm with the eye movement registration method:

- ESD are used at a deep level. Students do not only read them but they use them in view of their study process and directed towards further text comprehension (Poelmans et al, 1992 and Valcke et al, 1993);

When ESD are used at deep level and not just read superficially, this should be measurable in differences in eye movement patterns. The present research should therefore reveal that deep level

use of ESD can be measured by looking at specific reading times and reading times per word. In this research we cannot make use of number of fixations and average fixation length on text parts incorporating ESD because we use copies of printed text materials that contain too many text per window to make accurate estimates of these rates.
Differences in reading times and reading times per word can be expressed by negative and/or positive values. Certain ESD can invoke for instance longer or shorter reading times; this depends on the specific function/effect of the particular ESD researched. An ESD can imply that one only concentrates on a certain part of the text information and 'skips' the rest of the text by reading at a faster rate; e.g., when dealing with 'examples'.

We expect the following ESD to evoke longer total readings times and reading times per word: learning objectives (because subjects know they will be tested with a test based on the learning objectives); titles; margin texts (this is text that is stressed by margin texts, the reader knows that this text is of prime importance); text in italics; questions.
ESD that are expected to be read shorter: content page; introduction; examples; summary.
The ESD 'feedback' is expected to be read at an average rate. This depends on the information in the feedback. If it is new or unexpected for students it will be read longer per word, else it will de read shorter per word.
Schemes cannot be compared with 'standard' text because there is no adequate procedure to define the length of a standard text schemes are to be compared with. But, despite this inconvenience, this type of ESD is expected to produce 'jumps' in the reading process of a text in which they are embedded.

These basic arguments can be reformulated as the following three scientific hypotheses:

1. Comparing the reading time when reading ESD or standard text exhibits no significant differences.
2. Reading ESD or standard text produces no differences in reading times per word.
3. While reading 'schemes' there are no 'jumps' into the text.

Originally, building on the theoretical framework, also the influence of extra intra-individual variables on the use of ESD was predicted: Do poor readers use ESD in a different way compared to good readers? Are poor readers less well aware of functions of ESD and are they less well able to distinguish between basic information and 'examples' in study texts?
Unfortunately, the amount of students who volunteered for the eye movement registration research was too small. Consequently we were not able to study this research track. We did use however these variables to check for characteristics of the research sample.
This research will have an explorative function in the first place. We will pay much attention to the general experiences on working with this system and we will, in some cases, prefer qualitative analysis of data to quantitative research of data with statistical significance levels.
Nevertheless a set of scientific hypotheses is necessary to investigate the 'power' of the technique to reveal relevant differences in eye movement patterns in relation to ESD.

4 Research design

4.1 Research sample

First year law students were invited to participate in the study. A letter was sent to those students who wished to participate, confirming the date and place for the research. Eleven students participated. The sample consisted of 5 male and 6 female students. All students had prior knowledge of Governmental law. In section 4.7 statistical evidence is put forward that indicates the

representative nature of the research sample. A special condition to participate was put forward since subjects had to have normal uncorrected visual abilities. Wearing glasses or lenses would have resulted in unreliable eye movement monitoring.
The reader may expect that students of the Ou of the Netherlands participate in this study. But, students in a distance education setting have difficulties to get involved in a research setting; especially because of their combination of work and study and the fact they live at long travelling distances from the institute. For research purposes, we therefore selected a comparable sample of law students taking courses at a non-distance education university, the university of Limburg (RUL). Despite this differing setting, these students have experience with self-study and self-study materials because the educational university system builds on 'problem oriented learning'.
Moreover, before the experiment the students were given an introduction on the organization of Ou of the Netherlands course materials and the functions and effects of ESD. This was attempted to augment the correspondence of the actual research sample with the Ou-student population.
Students involved in the research, received a financial reward for participating.

4.2 Research instruments

4.2.1 Eye movement apparatus

The eye movement registration set-up contains a number of different components: a slide projector to project study texts on a screen in front of the subjects; the EYECATCHER, this is the actual eye-tracker, which samples the eye position every 20 milliseconds; the samples are logged using a data-acquisition computer; the eye movements are superimposed in real-time on an image of the study text and recorded on a VCR simultaneously; a video camcorder is used to record the overall set-up.
The projection screen is positioned at a distance of ± 80 centimetres. The slides represent almost exact copies of pages of a learning unit of the Ou-course 'Introduction to governmental law'. Each slide represents two pages. Since the learning unit consists of 15 pages, 8 slides are presented. Subjects can switch between slides like turning pages in a book with a remote control.
The EYECATCHER uses the corneal reflection/pupil centre method, which means that it calculates the fixation position from an infrared video image of the subject's eye. While reading, one eye of the subject is illuminated using an infrared radiation emitting diode (infrared LED). Infrared radiation is invisible for the human eye. The eye is monitored by an infrared-sensitive video CCD camera (For more technical information we refer to Stolk et al, 1991.).
A special computer program was used to convert the eye position samples into fixations. Fixations are characterized by their position and duration. Another program was used to analyze the eye movements. One option of the program is to reconstruct the actual scan-path of the subject. Figure 4 gives an example of such a 'chronological path'. The figure shows the path the eyes follow while reading/studying the text. The black squares in the figure represent sets of two or three subsequent fixation points. The bigger the squares, the longer the sum of the fixation durations has been.
However, there was one important problem in our way of using the EYECATCHER. The resolution of the EYECATCHER and similar systems is about 1 degree of arc, which equals 1,4 cm at a distance of 80 cm. The average distance between two subsequent words in the projection of the study text was below this value. If we assume that fixations fall in with subsequent words, it means that in this case it is impossible to reconstruct fixations from the original data set. It is well possible to reconstruct how long the eyes stay in larger text areas, such as sentences, sections and subsections.

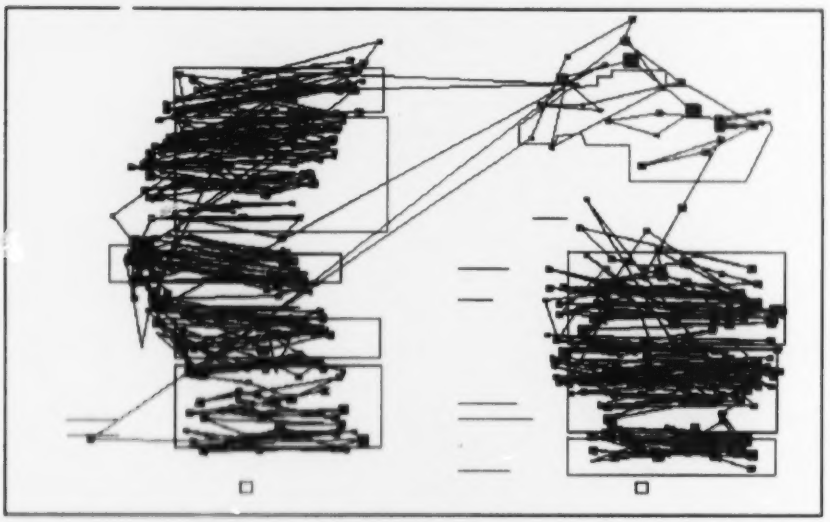

Figure 4: Pattern of eye movements during studying two pages of a law course

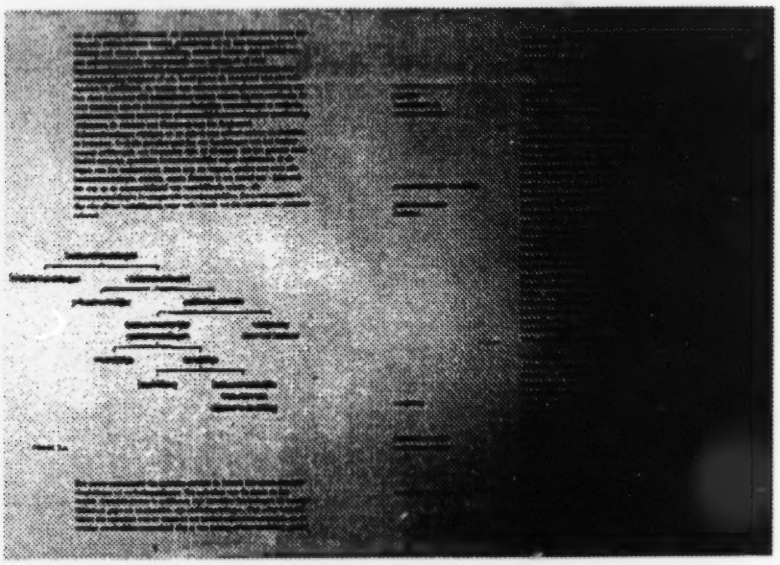

Figure 5: copy of a slide used in the research

4.2.2 Reading comprehension test

In the discussion of the theoretical base for this research, we already indicated that reading comprehension is a central component of the model for learning from printed study materials. Reading comprehension can be measured. To realize this, different alternatives are available:
-self-ratings.

The student is asked to value his own reading comprehension; for instance: "How many pages do you read in one hour?"; "Do you skip an article in the paper, because you didn't

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understand it?"
Answering these questions is not easy. They can be interpreted in different ways. It is also possible that students answer in a socially desirable way.

- *administration of an existing reading comprehension test.*
  No Dutch reading comprehension test is yet available at academic level. Research is currently done in this field by de Geus, Henneken & Reitsma (1992) but no results/instruments are available at this moment.
- *a test in a different language.*
  This implies translation of a test developed in a different language. This is not a desirable option since translation is difficult and affects the reliability of the new 'translated' test.
- *developing a new test.*
  Developing a new test seems to be the only acceptable alternative. For this and related research purposes, a reading comprehension test at academical level was developed. The test presented to the students 23 text fragments (e.g., texts of courses of the Ou of the Netherlands). Each text fragment was followed by two propositions. The student had to judge their congruence/discongruence with the text fragment. A try-out of the test resulted in major revisions. The new test version was again probed and adjusted anew. This procedure resulted in a final version based on 22 text fragments, each fragment contains two questions. This final version of the test had a reliability rate of .68. For a detailed description of the development of this test, we refer to Martens (in prep.)

4.2.3 Prior knowledge state test Law

To measure the prior knowledge state in relation to the law domain, a final test for the 'Basic course Law' has been adjusted. This was realized in close collaboration with a law-expert. The number of test items was reduced and several items were rewritten. The final test consists of 32 items: 20 multiple choice questions and 12 true/?/false questions. The quality of the items is checked with a special checklist (Poelmans, Martens, Valcke, Dochy & Bastiaens, 1993).

4.2.4 Questionnaire

The questionnaire constitutes of three different parts:

Part A contains general questions about study motivation, age, study habits, educational level, gender, etcetera. Motivation is measured in two ways: a self rating of one's motivation level and intrinsic versus extrinsic motivation.This information is used to compare the experimental with the control sample.

Part B contains questions about the course text the student had studied. They were asked to judge the clarity and difficulty of the text on a five points scale. These ratings helped to calculate the Learning Access Level (LAL) of the text version.

Part C includes questions about the specific embedded support devices. Each embedded support device is reviewed. The questions focus on the use of the support devices, their functions and effects and their appreciation by the student.

4.2.5 Comprehension test Governmental Law

The comprehension test measures the mastery of the objectives pursued by studying the specific learning unit. The original version of the learning unit contained a comprehension test based on open-ended questions. These questions were used to develop a new test for this research. The quality of the items was inspected with a special checklist (Poelmans et al, 1993). The final test consists of 23 questions: 16 true/?/false questions and 7 multiple choice questions. When analyzing the questions from a didactical perspective two subsets can be distinguished:

- 'knowledge questions' (13) checking the straightforward recapitulation of the content;
- 'insight questions' (10) measuring a more thorough insight in the domain.

The test was representative for the learning objectives pursued with the learning unit.

4.3 Research procedure

The research took place during two half day-periods.

- The first half-day period 47 students participated. The location was an auditorium of the university of Maastricht. The reading comprehension test, the prior knowledge state test and part A of the questionnaire were administered. After the session the students could choose between two research conditions:
  * studying a printed version of a learning unit (results of this research are reported in Martens et al, 1993).
  * studying in the experimental set-up with eye movement registration.
- Eleven persons volunteered to participate in the eye movement registration experiment. In section 4.6, the statistical analysis shows that - despite its small size - this experimental sub-group of students is representative as compared to the larger group of 47 students. 18 from the group of 47 students studied the same study material as our experimental group but with a printed version of the text instead of a projected version as used in the eye movement registration experiment. To summarize: 47 students filled in tests, form these 47 18 students studied the material form paper and 11 from slide projections.
- Eye movements registration procedure took place at the Open university in Heerlen. Before studying a learning unit of the course 'Introduction to Governmental Law' the subjects could read a short introduction to the learning unit. This introduction positioned the learning unit in its larger course-context and explained basic functions of ESD. This was necessary to deflate some differences with Ou-students, who by experience know about ESD.
- Students were informed about the procedure. They also were told that the procedure would end with a comprehension test about the learning unit studied/read.
- The procedure started with a calibration procedure to adjust the eye movement registration equipment to the individual student. This procedure requires the subject to fixate twenty calibration points, that are presented in four rows of five crosses on a calibration slide.
- The pages of the learning unit were also shown using a slide-projector. The student saw on each slide two pages such as he would see when reading from the printed version. The subject operated the slide-projector by means of a remote control. Learning was self-paced. Returning to previous pages/slides was allowed. The students were asked to study as in a normal situation. During studying an infra-red eye-tracker registered the eye movements of the student. Researchers made annotations about the sequence/order of the studied pages. Three researchers were involved, each with a different task during the experiment.
- After studying the learning unit, students were asked to answer the comprehension test and part B and C of the questionnaire. To motivate the students an extra financial reward of *f*25 (Dutch Guilders) was promised to two students with the highest comprehension test scores. A short interview concluded the experimental procedure.

4.4 Analyzing the registered data

The study text contains ESD. Fifteen areas in the text were defined, each subject to a specific different ESD. Some of these areas are shown in Figure 4. For each of these areas a similar text area was selected, that was not subject to an ESD. This resulted in area pairs, in which both elements had the same number of words. One element was subject to an ESD, the other was not. Both areas of a pair had the same position on a page. This enabled a comparison between text with and without ESD.

From the stored data, the ANALEYES software (Stolk, Smulders & Pelsmaeker, 1991) produced:
- the total reading time for each text area (in milliseconds);
- the number of jumps between text areas and schemes. When students read schemes they sometimes jump to the text and vice versa. This does not include the initial reading of the scheme. Only 'real jumps' to and from the text were counted.

The data set was entered into the computer to be processed with the *SPSS*[PC] and *SPSS for Windows* statistical packages. Scores for specific variables were processed as follows:
- Raw scores for the prior knowledge test, the reading comprehension test and the comprehension test Governmental Law were computed. This resulted in scores for three variables: total score prior knowledge, total score reading comprehension and total score comprehension Governmental Law. The comprehension test governmental Law consisted of 'knowledge' and 'insight' items. Sub-total score for 'knowledge' questions and 'insight' questions were computed. The variables that gave an indication of the use of a specific embedded support device were as well computed. The new variable gives an indication of the general use of embedded support devices.
- The variable 'student rating of Learning Access Level' (LAL) was constructed by combining the ratings of the different items in questionnaire B.

4.5 Reliability and validity of the research instruments

In analyzing the validity and reliability of the research instruments, the following considerations were regarded:
- All items of the reading comprehension test should measure the same aptitude (internal consistency). Items that correlate negatively should not be part of the test. Cronbach's alpha of the remaining items should be at least .65.
- The comprehension test and the prior knowledge test consist of two subsets of items testing different mastery levels (knowledge versus insight). Internal consistency is therefore not expected to be high. Moreover, the test items cover very different law topics; thus affecting again internal consistency.

We discuss the results by reviewing each research instrument separately:
- Reading comprehension
  Deleting test items who correlate negatively with the total score, 29 items remain in the final test. Crombach's alpha for this final test version is .68 (standardized).
- Learning access level (LAL)
  A total score of the student rating of learning access level (LAL) is computed by adding all scores of part B of the questionnaire. No item-analysis has been performed.
- Prior knowledge test
  We already indicated that internal consistency is expected to be low, considering the nature of the test.
  The content validity was ensured by choosing/adapting an existing test in cooperation with an expert in the law domain.
- Comprehension test
  We repeat the problem mentioned earlier in relation to the prior knowledge state test. Internal consistency is expected to be low, considering the nature of the test. No further reliability analysis has been performed.
  The content validity was also guaranteed by choosing/adapting an existing test in close collaboration with a law expert.

4.6 Checking for distracting aspects of the research set up

We already mentioned that the research set-up can be questioned when considering ecological validity:

- The subjects had to study from slides in a dark room with dimmed light in the presence of at least two researchers. The devices used for projection, eye movement registration and processing were substantially and quite 'dominantly' present.
- Reading from slides differs from reading from paper. One subject mentioned problems with text readability. After decreasing the distance to the screen he was able to read the text.
- Another problem is that the subjects knew that the researchers were able to see what they were reading. This may have influenced their normal reading style.
- It could take quite some time (up to 35 minutes) before the eye-tracker all was calibrated rightly. During this period the subject had to wait.
- The chair of the experimental set-up was a so-called Röntgen-chair with which the subjects were unfamiliar.

In practice the research set-up proved to work better than we had foreseen. After a short period the students were used to the special setting and seemed to work in a concentrated way. By means of a short interview the students were asked afterwards to react to the set-up. All subjects indicated that they studied in a quite normal way and that they experienced no particular problems with this set-up. The only exception was the student who mentioned readability problems which could be solved before the experiment started.

In order to check for the distracting influence on the learning process we also compared learning outcomes from the research sample with the outcomes of students studying the same text, but as printed on paper. These students were from the same university, the same study year and they studied the same subject as our research sample.

Table 2: Learning outcomes from research sample 'slide' versus sample 'paper': t-tests, two-way probability

variable	group 'eye'(n=11) average score	group 'paper' (n=18) average score	D.F.	t-value
comprehension test total score	14.73	15.14	45	-.36
knowledge questions	8.7	8.14	45	.39
insight questions	6.0	7.0	45	-1.41
use of ESD	7.55	8.33	27	-1.77
rating LAL	44.0	46.33	45	-1.06

* $p< 0.05$; ** $p< 0.01$

Table 2 indicates that students in the research set-up do not differ from students in a normal study condition. Slide projection does not significantly influence comprehension scores, self ratings of use of ESD, nor ratings of learning access level when compared to learning from a 'normal' printed version of an Ou course.
However, some caution is still appropriate. Although none of the t-tests produced significant results, a trend can be perceived. Four out of five comparisons between the two research samples are in favour of learning from a printed version (negative t-values). therefore we conclude that there might be a small, negative influence from the research set up with slide projections, although

this influence is too small to raise significant differences.

4.7 Checking the characteristics of the research sample

The 11 volunteers in this research can be compared to a larger sample of 36 students who participated in a parallel research set-up where their approach to studying form text was analyzed. The two samples were compared on seven variables: educational level, self rating of motivation (two measures), prior knowledge, reading comprehension, sex and age. The results of the t-tests are presented in Table 3.

Table 3: Comparisons between characteristics of research sample with other sample: t-tests, two-way probability

variable	group 'eye'(n=11) average score	group 'paper'(n=36) average score	D.F.	t-value
educational level	2.2 (n=10)	2.44	33.05	-1.21
self rating of motivation (1)	1.18	1.08	45	.92
self rating of motivation (2)	3.55	3.95	12.47	-1.34
prior knowledge	10.27	9.14	45	-.17
reading comprehension	11.56	11.95	45	.87
sex""	1.55	1.55	45	-.06
age	20.64	20.28	45	.55

' $p< 0.05$; " $p< 0.01$; "" 1=male; 2=female

Table 3 shows that the 11 students do not differ significantly from the other students in the larger research sample. The students who enroled voluntarily for the experiment of eye movement registration do not appear to be a 'special' subgroup of a larger research sample.

5 Results

5.1 General conclusions

Some preliminary remarks

- Due to a technical problem the data of one subject could not be used for further analysis.
- The reader may notice that 'comparable standard text' areas are not compared with each

other in Table 4. This is not done because it is not directly relevant for the hypothesis testing. Another reason for not comparing standard texts is that they are not of the same length. However, to control for an -unexpected- influence of differences in reading time for standard texts, we made some comparisons between standard texts of about the same length. therefore, such areas - of about the same length - were compared with one another. No significant differences were found in total reading time.
Considering these preliminary analysis results, we concluded that comparison at the level of ESD areas was acceptable. After a first analysis of the results we will further evaluate the usefulness of the comparisons between these text areas.

Table 4 shows the average reading times in milliseconds of ten subjects on the fifteen predefined area pairs. The left column describes the areas that are subject to an ESD, the right column contains the results on areas similar to the areas of the left column, but that were not subject to an ESD. 'Schemes' are dealt with separately (cf. Table 6).

Table 4: Average reading times in milliseconds per window and pairwise T-tests (two way probability, N=10; 9 d.f)

variable	registrations				
	ESD		standard text		t-value total reading time
	total reading time	SD	total reading time	SD	
content page	6238	6195	14244	7522	-2.89*
introduction	9086	3749	14262	7532	-2.17
learning objectives	52432	29907	57096	20783	-.83
title	2118	1814	9201	21114	-1.04
margin text 1	26900	8152	21366	7226	1.84*
margin text 2	12426	6929	9796	7615	.75
example 1	42672	14498	45692	14242	-.57
example 2	23578	6673	31002	13894	-1.77
example 3	41082	11125	46938	12382	-1.43
text in italics	7274	3693	10418	4644	-2.11*
question 1	18788	11762	9729	8563	2.08*
question 2	22160	11567	6951	3712	4.11**
summary	25678	16007	35464	13161	-1.29
feedback 1	32998	25492	36500	13761	-.39
feedback 2	42518	17262	36500	13762	1.00

* $p < 0.05$; ** $p < 0.01$

When we divide the total reading time per window as printed in Table four by the number of words per window it turns out that the preliminary conclusions of equality of standard texts is not

correct. This means that the notion of comparable standard text based upon areas of expected normal reading is not valid in the way we have defined it. When calculating the total reading per word (see Table 5) it shows that the variably in reading time per word for these areas is too high. This is especially the case for the relatively small areas with only a few words. This has two important consequences:

1. Variables that are based on windows containing 20 or less words are deleted from further analysis ('title' and 'text in italics'). These two variables also have extreme high reading times per word (836 and 744 milliseconds) and very high standard deviations. These values are higher than any others in Table 5. We consider these measures as unreliable.
2. The results as reported in Table 4 should be treated with caution. 'Standard' texts are not really standard. Standard text evokes differences in reading time per word and therefore windows containing standard text can not be considered equal. Therefore it seems better to construct one general variable to compare ESD with. This can by done be computing the mean reading time per word for all the data we have obtained (both reading times per word for ESD and for 'standard' text). This value is 344 milliseconds.

Table 5: Reading times per word in milliseconds and comparisons with mean (binomial test; one-tailed probability, for feedback 1 and 2: two-tailed probability)

variable	registrations						
	ESD				comparable standard text		
	number of words	total reading time	reading time per word	binomial test, sign	number of words	total reading time	reading time per word
content page	39	6238	124	-**	40	14244	356
introduction	50	9086	159	-**	52	14262	274
learning objectives	101	52432	519	+	109	57096	523
margin text 1	56	26900	480	+	70	21366	305
margin text 2	40	12426	311	-	44	9796	22
example 1	166	42672	257	-*	168	45692	272
example 2	75	23578	314	-	85	31002	364
example 3	134	41082	307	-	132	46938	356
question 1	29	18788	648	+	33	9729	295
question 2	40	22160	554	+	43	6951	162
summary	92	25678	279	-	92	35464	385
feedback 1	102	32998	323	-	100	36500	365
feedback 2	104	42518	409	+	100	36500	365

* $p < 0.05$; ** $p < 0.01$

What conclusion can be drawn from Table 5?
In Table 5 we look at the reading times per word. A comparison of the reading times per words in our experimental results with Rayner and Pollatsek's figures in Table 1 shows that in general the reading times per word are higher in our case.
ESD are read 360 milliseconds and standard texts 327 milliseconds. In Table 5 reading times per

word for ESD are compared with the average value of 344 milliseconds in the column 'sign'. A positive sign indicates that the reading time per word is higher and a negative sign indicates the opposite. Note that 'reading time per word' is not based on dividing the total reading time by the number of words for all cases together but that this is done for each case separately. From these values the mean is calculated which is printed in the column 'reading time per word'. Also note that we make use of round values.
We have performed statistical analysis on these signs with a nonparametric sign test (binomial test). We had to choose for a nonparametric test for this particular analysis because of non-normal characteristics of the variables we used here. However we opt for a more qualitative interpretation of the obtained data than an interpretation that is based on significance levels. First of all this is related with the explorative character of this study. Second with the limited number of subjects and on the third place does the use of a nonparametric sign test imply that a lot of information is lost.
Although there is a lot of variance between 'standard texts' that we cannot explain and that is possibly due to content differences between these fragments of standard text, it is remarkably that the signs as printed in Table 5 are quite well in line with our hypotheses. We repeat the expected differences between ESD:
longer total readings times and reading times per word were expected for:
learning objectives; titles (not analyzed); margin texts (this is text that is stressed by margin texts, the reader knows that this text is of prime importance); text in italics (not analyzed); questions.
ESD that are read shorter: content page; introduction; examples; summary. The ESD feedback is expected to be read at an average rate.
ESD that were expected to evoke shorter reading times per word do so in most cases and ESD that were expected to be read longer per word also do so. There is one exception: margin text 1 has a positive sign and margin text 2 has a negative sign. The explanation for this may be situated in the content of the text fragment. We will not discuss this governmental law issue here. Feedback 1 has a positive sign and feedback 2 has a negative sign. This is quite well in line with the expectations since we expected feedback to yield average reading times. Both values for feedback do not differ much from the overall average of 344 milliseconds per word.

5.2 Looking at schemes

As stated earlier schemes have to be handled in a different way. Schemes cannot be compared with standard text because there is no adequate procedure to decide about the length of the standard text. Schemes are expected to evoke 'jumps' in the text.
In Table 6 we counted the number of jumps to the text. On average, each scheme evokes 3.6 jumps to the rest of the text.

Table 6: Eye movement registration data in relation to schemes

schemes	number of fixations	total reading time (msec)	average fixation length	jumps in text
scheme 1	86.6	43402	501	3.7
scheme 2	24.7	12735	516	2.5
scheme 3	45.7	25770	564	4.5

5.3 Supplementary results

The data we could collect with the program ANALEYES were extensive. In this section we will present some additive information, that is not directly linked to hypothesis testing but that is, in our opinion relevant.

- To examine if all ESD have been read/used by the students, we controlled the individual data files. It turned out that every ESD was looked at, at least once by each student. In more technical terms: for each student there was at least one observation per ESD.
- Inspection of video recordings of the eye movements and inspection of patterns of eye movements during studying the course (such as in Figure 4) showed important differences in reading style. We have not statistically examined these differences between reading patterns because the research sample was too small for such complicated analyses.
- The inspection of the individual data files also revealed that there are differences in study approach. Some students (n=5) tend to reread while others (n=5) only read the text once. By 'rehearsing' we mean that a subject reread at least one ESD.
- Because of the small sample size no comparisons were made between subjects, considering specific intra-individual variables (e.g., prior knowledge, gender, etcetera).

6 Discussion

6.1 Conclusions

We repeat the 3 scientific hypotheses: comparing the reading time when reading ESD or standard text exhibits no significant differences; reading ESD or standard text produces no differences in reading times per word; while reading 'schemes' there are no 'jumps' in to the text.

Considering the results, the following can be concluded:

1 Hypothesis 1 can not be answered. Although we found the expected differences the variability along the variables that measure standard text was too large.
2 ESD evoke differences in average reading time per word. These differences are in line with our expectations.
3 We have counted the number of jumps to the text: on average there are 3.6 jumps from a scheme to the rest of the text.

Accepting these results, two out of three hypotheses can be rejected.

We expected that when ESD are used at a deep level and not just read superficially, this could be observed in differences in eye movement patterns. The actual research has shown that deep level use of ESD is in fact measurable when considering reading time per word.
In our opinion the statement that deep level use of ESD is measurable applies to ESD that elicit longer reading as well as to ESD that elicit shorter reading. Deep level use of an ESD can for instance imply that a student concentrates only on a certain part of the text and 'skips' the rest of the information. The latter is the case with 'examples' and 'content pages'.

These results confirm the outcomes of previous research on the use of ESD.
In Poelmans et al (1992) and Valcke et al (1993) we concluded that ESD are used at a deep level. Students do not only read them but they read them in function of their study process to reach a

better comprehension.

The research presented here also embodies an important 'learning' episode for our own future research practice. As far as we know the use of ESD was never before researched by means of eye movement registrations, although the technique of eye movement registration is commonly used (McConckie and Rayner, 1975; Rothkopf & Billington, 1979; Mandel, 1979; Just & Carpenter 1980; van Lieshout, 1982; Shebilske & Fisher 1981, 1983; Grabe et al, 1987; Blanchard & Iran-Nejad, 1987; Vauras, Hyönä and Niemi, 1992; Britt et al, 1992).
In our opinion, the technique has proven to have the potential to deliver adequate and reliable results. For that purpose some minor and major adaptations of the research setup are required. These adaptations are described in the following section.

6.2 Alternative set-up for experiments on eye movement registration and ESD

Reconsideration of the experiments using eye movement registration for ESD-related research, shows that the early decision of using standard Ou course material as stimulus material for the experiments has made the final analysis and interpretation of the results very difficult. The limited resolution of the eye movement measurement technique, which is a direct result of the need for a low subject load, in combination with the small text font and huge information density of one page of Ou course material, makes that from the wide range of eye movement parameters (such as number of fixations and fixation length) only the reading time can be used.
Reading time seems to be an important indicator for the distribution of attention on different areas. However, in the regions that are not dominated by text, such as schemes and pictures, additional parameters related to the identification of single fixations seem to be an important extra source of information.

An additional problem resulting from the use of complete pages of very complex juridical course material is that there are numerous factors that may have an influence on reading time. It is hardly possible to quantify most of these factors. Boundary conditions for ecological validity set lower limits to the amount of the stimulus material in order to get a realistic educational setting. However, the actual analysis of eye movements should be limited to only part of the total amount of material containing a few well-chosen ESD's. Within this context it is important to verify whether the concept of standard text, in the sense of text without ESD, is valid. This means that it is necessary to investigate to what extent 'eye movement related' characteristics for individual subjects can be defined for reading behaviour on the type of study material that is used in the experiments.

It is necessary to look for a presentation medium that allows for the presentation of only a limited amount of information at a time, which makes it possible to identify single fixations. On the other hand such an information packet must be part of a total package of study material with a realistic size. The presentation medium that is used must offer proper tools to the subjects and allow them navigate through the material in a proper way.

If it is one of the aims of a follow-up research project to draw conclusions that are valid for groups of subjects, individual differences make it necessary to define a minimum number of subjects for the experiments.

Summarizing we can say:
- that the stimulus material that is to be used should be analyzed or even constructed properly in the context of the research questions
- more than it was the case in the current research, stimulus material should be analyzed and constructed at a micro level; the way in which ESD's affect eye movement parameters should be

isolated from other variables that may affect these parameters
- when the stimulus material is constructed, the resolution of the eye movement equipment must be taken into account; a criterium can be that it must be possible to identify single words as target of single fixations. This would make it possible to use, besides total reading time per window and jumps from schemes, parameters such as number of fixations and fixation length.

6.3 Future research

With the adaptations described above eye movement registration can become a useful tool for future research on use of ESD. The promise for future research might especially be true if this objective measurement technique could be used in combination with the less objective research methods, such as questionnaire and interview.

Due to the innovative character of our research, we devoted substantial attention to the potential distracting influence of the research set-up. We compared the study outcomes of the eleven students with the behaviour and characteristics of another sample that studied the same text but from a normal paper version. It was concluded that there is a small, but not significant, negative influence from the research set-up on study success. Also the interview sessions confirmed that the research set up was not very distracting. The latter might be due to the new and special elaboration of the eye movement registration device and the computer program ANALEYES for analysis which made possible that subjects had relatively large 'movement tolerance' (Stolk et al, 1991).
Originally, this research also was intended to investigate the influence of intra-individual student variables on the use of ESD: for instance "Do poor readers use ESD in a different way when compared to good readers? Are poor readers less well aware of functions of ESD and are they for instance less well able to distinct between basis information and examples in a study text?" Due to the limited amount of students involved, more advanced statistical analyses considering these intra-individual variables were irrelevant or impossible. Future research might be interesting.

One disadvantage of the research method that remains is related to the high investment in time to gather and analyze the data. The research involves individual students and the analysis takes a lot of time. For the future we hope that it is possible to automatize - parts of - the research procedure.

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